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Rice ecologies of India and their soil fertility status

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Abstract
Rice in India ranks first in the use of land (44 million ha), water (more than 50% irrigation water) and inputs (38-40% of fertilizers and 17 – 18% pesticides) and is grown in diversified environments viz., water logged to rainfed uplands, jhums to deep water, high humid to arid temperatures and flood prone to drylands. Soils are so extraordinarily varied that there is hardly any type or texture of soils on which rice cannot be grown viz. acid peaty soils of Kerala (pH 3), highly alkaline soils (pH 8.5 & above) of Punjab, Haryana and Uttar Pradesh. It is cultivated exclusively as a rainfed crop in areas with precarious monsoon and unpredictable rainfall distribution. It is also raised in areas where water level reaches 5 metres or more. The rice culture in Kuttanad district of Kerala is below the sea level, while in the states of Jammu and Kashmir, it is grown almost upto an altitude of 2000 msl (6600 ft). A wide range of rainfall distribution pattern (drought, submergence, deepwater) and distinct differences in soils (coastal and inland salinity, alkalinity, acidity), agro-climatic situations (high humidity) and seasons has resulted in the cultivation of thousands of varieties and one can see a standing rice crop at some part of the country or the other in any time of the year.

Keywords: Rice Ecologies, Soil Health

Introduction
Rice having the largest area (~ 45.0 million ha) in the country and is grown in a variety of soil types with wide range of characteristics. The rice-wheat production system has played an important role in the food security and has remained its cornerstone for rural development and natural resource conservation. More than 15 major soil groups of diverse characteristics are cropped to rice under different ecosystems (rain fed upland to deep water and irrigated), and agro climatic conditions. Rice is grown in 11 out of 15 agro-climatic zones (west and eastern Himalayas, IGP, major portion of southern and eastern plateau region, eastern and western coastal region and the islands of Indian Ocean) (*K V Rao et al.*, 2013) [1]. Predominantly alluvial soils, red and yellow loams, shallow to deep black soils and lateritic soils are cultivated to rice. More than 50% of land area in the country is affected by various soil problems that influence the agricultural productivity. In brief, the soil characteristics vary widely from sandy loam to clay in texture; soil pH from 3.0-10.5; organic carbon from 0.2 to > 2.0%; cation exchange capacity (me/100g soil) from < 10.0 – 50.0; and very low to high available nutrient status. But, now evidences of second generation problems have started appearing such as declining productivity, plateauing of crop productivity, declining soil organic matter, receding ground water table, diminishing farm profitability etc., which are mainly attributed to intensive conventional production systems.
Therefore it is very pertinent to highlight the present fertility status of rice soils of India in terms of its constraints.

Rice Ecologies in India and their characteristic features
Rice is thus cultivated under 4 ecosystems.
- Irrigated wet lands (55% in world and 45% in India).
- Shallow rainfed lowlands (25% in world and 33% in India).
- Rainfed uplands (12% in world and 15% in India).
- Deep water rice (8% in world and 7% in India).

The important production constraints under each of the ecosystem are

Irrigated ecosystem: Irrigated rice culture is found in alluvial/phreatic/fluxial areas. Fluxual lands (Kuttanadu areas of Kerala) needs such as polder and dikes construction to prevent excessive flooding/intrusion of sea water. Facilities of drainage (lift by power operated pumps) in monsoon season and irrigation in summer are required. Pluvial lands are generally bets suited for irrigation.

Rice is grown in bunded fields into which irrigation system fed from reservoirs/tanks wells control the depth of water (2-5 cm). Rice is physiologically, morphologically and anatomically adopted to grow in these flooded soil conditions. Indeed, flooding provides several benefits, chief of them include weed control and improved soil fertility (P, Fe, Mn). Crop is raised with full recommended package and average yield levels are around 5.0 t/ha. Green revolution observed in mid 60s and 70s was infact due to several of the favourable factors associated with these irrigated lands. But of late there is a set back in the form of deceleration/plateauing/decline in rice yields, partly due to deterioration in soil quality in terms of fertility (Zn, Mn, alkalinity, salinity), physical (structural degradation) and biological (impaired mineralisation) factors and partly due to increased biotic stresses (pest and diseases) (*K V Rao et al.*, 2013) [1].

Rainfed lowlands

Rainfed low lands are more or less comparable to irrigated systems in the sense that these fields are also bunded and runoff water from copious monsoon rains cause moderate accumulation of water. But variability in the rainfall (stochastical variation) is the major risk encountered. In view of these constraints, the yield levels in rainfed low lands are generally less than in irrigated areas (2-3 t/ha). Possibility of raising two rainfed rice crops need to be explored in this system.

Rainfed uplands: (Asia, Latin America, Africa)

The major yield determining factor is nature of rainfall. The quantum (800-1600 mm) and distribution of precipitation are of paramount importance. Upland rice needs atleast 600 mm rainfall to complete its growing cycle provided the rain is distributed evenly (200 mm monthly). In Latin America, 1000 mm is considered as minimum with 200 mm monthly rainfall. In general, conditions for growing dryland rice appear to be sub-marginal where annual rainfall is less than 1000 mm except for clayey soils with high water holding capacity. Usually sandy soils are not suitable for uplands unless rainfall exceeds 1600 mm where soil retention capacity is immaterial. Here rice is grown in leveled, unbunded fields like any other cereal invariably in monsoon or wet season. Land is prepared before rainy season and seed is either broadcast or sown using country plough or seed drill. Understandably little fertilizer is applied as it is risk prone and farmers are invariably poor. Rain water is not held as there is no bunding. But in some places, water harvesting is practiced (akasavai) by raising small cross bunds. Weeds are the major problem and chief reason for the poor yields (0.8 - 1.2 t/ha) is attributable to this factor.

Deep water /floating rice: (Bangladesh, Thailand, Burma, India, Vietnam, Indonesia, West Africa)

Rice is cultivated here in water depth ranging from 0.5 to 5.0 m. Nevertheless no food crop other than deep water rice can be grown under such flooded areas. The duration of flood water may last from 3 to 10 months commonly in Asia but in Africa it may extend upto 8-10 months.

Nutrient mining status

The soil fertility status of Indian soils has declined drastically over the years following the era of green revolution and is marked by a negative balance of 8-10 M. tons between nutrients removed by the crops and those added through manures and fertilizers leading to mining of soil nutrient capital and steady reduction in soil nutrient supplying capacity. Besides this, nutrient losses through various means are alarmingly large which are rarely taken into account. The loss through soil erosion is second to nutrient removal by crops. About 8 M t of plant nutrients are lost through water erosion of soil (5.3 billion t) while estimates of leaching and gaseous losses are not available. Even in well managed cropping systems like rice-wheat raised on currently recommended nutrient levels, depletion of soil fertility has been reported. Considering the projected food grain demand and fertilizer consumption by 2010 and 2025, this gap is likely to increase to 11 and 13.3 Mt of NPK, respectively.

The situation is further aggravated by the depletion of major soil nutrients like N and K in intensive cropping systems and emergence of wide spread deficiencies of secondary (S, Ca) and micronutrients (Zn, Fe, Mn, Cu and B). Soil test data available for major part of the country for the major nutrients (N, P, K) show that 89 and 80% of the soils are low to medium in N and P, and about 50% of the soils are responsive to K supply. District wise soil fertility status of Indian soils also indicates a similar trend. The deficiency of Fe was found to be largest 26% in Haryana followed by 18% in Tamil Nadu, 12% in Punjab and 8 to 9% in calcareous soil of Gujarat and Uttar Pradesh. Adoption of rice-wheat cropping system in place of maize-wheat or groundnut-wheat in non-traditional rice growing areas on highly permeable coarse-textured soils of Punjab and Haryana has been responsible for occurrence of Mn deficiency (33%) particularly in wheat. The extent of boron (B) deficiency varied from 2% in Gujarat to 68% in West Bengal. In general B deficiency is most wide spread in the red and lateritic soils of Karnataka, leached and acid soils of West Bengal, Jharkhand, Orissa and Maharashtra (56%), and in highly calcareous old alluvium of Bihar (22-45%) (*K V Rao et al.*, 2013) [1] (Table 1).

Table 1: Distribution of problem soils in India cropped to rice.

Soils	Area (m ha)	States
Sodic	2.5-3.0	Uttar Pradesh, Punjab, Haryana, Andhra Pradesh, Bihar, Maharashtra, Karnataka, Tamil Nadu
Inland Saline	2.4	Uttar Pradesh, Haryana, Punjab, Rajasthan,
Potential	(15.0)	Maharashtra, Gujarat, Karnataka, Andhra Pradesh,
Coastal saline	2.5-3.0	West Bengal, Orissa, Andhra Pradesh, Tamil Nadu, Kerala, Karnataka, Maharashtra
Acid soils	49.0 (15.0)	North East Hills, West Bengal, Orissa, North Coastal Andhra Pradesh, Kerala, Karnataka, Goa, Bihar
Acid saline	0.5-1.0	Kerala, West Bengal
Nutrient problems	Deficiency	N,P,Zn,Fe,S,K,Ca,Mn
	Toxicity	Fe,H_2S,Al, As,Se

Soil acidity and related Problems

More than 15 m ha of rice area in India in the states of Kerala, Karnataka, Goa, North Coastal AP, Odisha, Jharkhand, Chhattisgarh, West Bengal, Himachal Pradesh, North east hill region, Assam and Tamil Nadu have acidic soils of varying degree of constraints associated with soil acidity which influence crop productivity. Acid alluvial soils are present in West Bengal, Assam and Orissa (*K V Rao et al.*, 2013) [1].

Characteristics: The soils are coarse - textured with compact surface, poor physical structure and aggregate stability, high infiltration rate, low water holding capacity (WHC), high permeability, are prone to crusting and compaction (higher bulk density- BD) effecting seed germination. The soils have low pH (2.8-6.5), clay fraction with minerals of low surfaces and low CEC, low base saturation (16-67%) and high amounts of exchangeable Al, H^+, Fe and Mn saturation, high P fixing capacity, and general low available status of Ca, K, Mg, P, Mo, B, Si and high levels of Fe, Al, Mn, Zn, toxicity of organic acids, and reduced microbial activity.

Table 2: Expected loss of productivity due to soil acidity

Class	pH	Degree	Loss in productivity (%)
0	>6.5	Nil	Nil
1	5.5-6.5	Slight	Upto 10
2	4.5-5.5	Moderate	10-25
3	3.5-4.5	Strong	25-50
4	<3.5	Extreme	>50

Acid sulfate soils: In a small area in coastal lowlands of Kerala and West Bengal soils of high acidity and organic matter content (peaty soils) are located. The acid sulfate soils in Kerala, locally known as Kari soils, do not have the typical characteristics of a tropical peat soil. These cover an area of 1.1 m ha in Kerala. A part of these in west coast are saline (26,000 ha), and swamp soils (2,500 ha) located 2-3 m below sea level. Some of the important chemical characteristics of these soils are: very low pH 3.0-3.5; high EC 4.6-15.0 dS/m; high OC 1.8-7.1%, soluble Fe (0.1%), Al 28-235 ppm and SO_4 (11-19 me/100g soil) with high lime requirement (11-17 t/ha) and very low available P status. The deficiency of Mo is common in acid soils of humid region. Distribution of micronutrients deficiencies across AEZ indicate zinc deficiency to be about 40% in 1, 2, 5,15,16,18,and 19 zones; 40-50% in 9,11and 12 zones; 50-55% in 4, 7, and 13, and 55% in the remaining zones. Soils of indo-gangetic plains showed 55, 47 and 36% zinc deficiency in trans-northern, central and eastern parts of IGP, while boron deficiency is 8, 37 and 68% in these regions of IGP. Boron deficiency varies from 2 % in AER 2; 24-48 % in highly calcareous soils of AEZ 2, 9, and 14 and is most wide spread (39-68 %) in red and lateritic soils of AEZ 6,13,16,17 and 19. Deficiencies of Cu and Mn were found sporadic. The problem of Fe and Mn deficiency has emerged in Trans-northern IGP (zone 9) more so under rice-wheat cropping while most of the soils tested adequate in available iron. Its deficiency in all AEZs as well as toxicity in some coastal, submontane and red-lateritic soils is quite common (*K V Rao et al.*, 2013) [1].

Low fertility of Indian soils is the major constraint in achieving high productivity goals. In both agriculturally-advanced irrigated ecosystems and the less-endowed rainfed regions, nutrient replenishment through fertilizers and manures remains far below crop removal, thus causing the mining of native nutrient reserves over years. Widespread deficiencies of N, P, K, S, Zn and B have emerged, and significant crop responses to application of these nutrients are reported. The deficiencies are so intense and severe that visual symptoms are very often observed in major crops (*Sreedevi et al., 2015)* [3].

Soil fertility decline is naturally more alarming in intensively cultivated regions wherein nutrient withdrawals by crops are high and replenishment is not only inadequate, but also unbalanced in favour of N. Soil nutrient depletion has grave implications in terms of (i) more acute and widespread deficiencies, (ii) declining nutrient use efficiency and returns from money spent on nutrient and other inputs, (iii) a weakened foundation for high yielding sustainable farming, and (iv) escalating remedial costs for rebuilding depleted soils. Experimental evidences suggest the productivity on high fertility soil is often greater than that obtained on low fertility soil despite nutrient use in optimum quantities on both soils. Maintaining soil fertility at high levels through careful appraisal and soil-test based judicious nutrient use is an assured way to attain and sustain maximum economic yields.

Recent studies (on-station as well as on-farm) in rice-wheat cropping system revealed that soil-test based site-specific nutrient management could enhance the annual productivity of the system up to 2–2.5 times over the prevailing ad hoc nutrient management adopted by the farmers. Although soil testing is a powerful tool to support high productivity by way of rationalizing nutrient use, its current impact on farm practice is presently not visible. In order to make it effective and farmer service oriented, it is imperative on the part of STLs to (i) expand the arena of soil testing beyond NPK, and (ii) develop fertilizer recommendations for high yield targets, involving all deficient nutrients and exploiting important positive nutrient interactions. In this context, at least two critical areas require the attention of researchers.

Intensive agriculture without judicious replenishment of plant nutrients leads to multi-nutrient deficiencies in soil. Unbalanced and inadequate nutrient use in most areas, and an indiscriminate use of N fertilizers in some agriculturally developed regions, are the common features of Indian farming, which are considered as potential threats to sustainability of intensive production systems. Unfortunately, fertilizer recommendations of most states inadvertently promote unbalanced fertilization, for these recommendations neither take into account crop yield levels nor the emerging multi-nutrient deficiencies. For developing rational site-specific fertilizer management schedules to match the changing soil fertility scenario and the demands of nutrient exhaustive intensive production systems, pragmatic information on changing soil fertility status of diverse agro-ecologies is a pre-requisite. The present report includes fertility appraisal of soil samples representing 10 districts and 9 AESRs, namely: Banaskantha (AESR 2.3), Mehsana (AESR 4.2), Nasik and Aurangabad (AESR 6.2), Udam Singh Nagar (AESR 9.1), Chhindwara (AESR 10.4), Jammu (AESR 14.2), Kangra (AESR 14.3), Ganjam (AESR 18.4), and Baleswar (AESR 18.5). Instead of explaining soil fertility status on the basis of conventional low, medium, and high fertility classes, we categorized the soils into fertilizer responsive and non-responsive categories for individual nutrients. Attempts were also made to assess the extent of multi-nutrient inadequacy in the soils of different AESRs.

Deficiencies of nitrogen (N) and potassium (K) were universal. More than 80% soil samples from Banaskantha, Mehsana, Aurangabad, Ganjam and Baleswar containing =0.75% organic carbon (C) were placed in the N-responsive category. Organic C content was relatively high in soils of hilly and Tarairegions of Kangra, Jammu, and Udham Singh Nagar. The magnitude of responsiveness to K varied from 28% in Nasik to as high as 100% in Udham Singh Nagar. In the soils of Banaskantha, Mehsana, Jammu, Kangra, and Ganjam, more than 70% of the samples fell in the K-responsive category. Soil responsiveness to phosphorus (P) was recorded in all districts, except Udham Singh Nagar, and the magnitude varied from 12% in Chhindwara to 84% in Aurangabad. Widespread deficiencies of sulfur (S) were observed in the soils of Chhindwara and Mehsana with 66% and 34% samples, respectively in the S-responsive category. The S inadequacy problem was not of much significance in other districts. Among micronutrients, zinc (Zn) deficiency occurred in more than half of the samples from Aurangabad and Jammu Districts, whereas iron (Fe) deficiencies were common in Nasik and Banaskantha (*Surekha et al*., 2015) [2]. Multi-nutrient inadequacy of varying magnitude was present in all AESRs, though the nutrient adequacy groups were different. Whereas NK inadequacy was frequently observed in Banaskantha, Mehsana, and Ganjam, PK was the dominant inadequacy group in Kangra, PKZn in Jammu, KS in Chhindwara, NP in Baleswar, NPZn in Aurangabad, and PFe in Nasik. Across the districts and AESRs, NK appeared the most widespread multi-nutrient inadequacy combination, followed by NPK, NP, PK, and PKZn. Incidentally, NK was the dominant nutrient inadequacy group for the soils of seven AESRs also.

Statewise rice productivity and related soil fertility constraints

Andhra Pradesh

Rice Productivity

Cuddapah district has rice productivity in the second zone ie medium productivity where rice productivity falls in 2,000-2,500 Kg/Hectare and related soil fertility in terms of low available P is evident from the table. Although Vishkhapatnam district has medium NPK status, but due to less area under rice productity is less. Srikakulum district rice productivity falls under Low-Productivity ie 1,000-1,500 Kg/Hectare and available P and K is low. Rest all the district of Andhra Pradesh are having high rice productivity and related soil available NPK status is medium to high.

Other soil related constraints

1. Red soils of the region are readily to moderately permeable. Permeability decreases with soil depth
2. The soils are mostly non –saline to slightly saline
3. Twenty five percent of the soils are clayey in nature and drainage is a problem
4. Zn deficiency is a serious problem in Telengana, Nagarjunasagar and Sriramsagar, Kurnool-Cuddaph areas.
5. Potassium depletion is generally slow in Black soils(even upto 19 crops), however the depletion is rapid in red soils.
6. Potassium is slowly becoming a major limiting factor in coarse textured soils.
7. Sulphide injury has been reported in red and black soils of NSP left canal area.
8. Extent and distribution of problem soils in the state such as saline, sodic and acid soils is not available.
9. STCR for rainfed areas are available for a limited scale which can impact nutrient use efficiency.
10. Crusting is a major problem in vertisols, chalka soils when wetting and desiccation sequences occur.
11. Fertilizer recommendations based on soil test data needs regular updating.
12. Nutrient interactions studies and its potential use in fertilizer recommendation can bring benefit to poor and resource poor farmers.
13. Narrow workable soil moisture range in black soils.
14. Sub soil sodicity affecting soil structure, drainage and oxygen availability.

Bihar

Rice Productivity

Darbhanga and Khagaria has very low rice productivity(<1t/ha) due to very low available NPK status., Madhubani, Muzaffarpur, Paschim Champaran, Sitamarhi falls under very low rice productivity(<1t/ha) due to very low available P and K status. Begusari, Gopalganj, Munger and Saran districts are low in rice productivity where it ranges from 1-1.5t/ha. The available P and K status is highly limiting.

Other soil fertility constraints

1. Widespread deficiency of Zn has been reported from the old alluvial soils.
2. Iron deficiency has been reported from the calcareous alluvial soils.
3. Fertilizer recommendations based on soil test data needs regular updating.
4. Nutrient interactions studies and its potential use in fertilizer recommendation can bring benefit to resource poor farmers.
5. Some districts of Bihar such as Patna, Gaya and other rice growing regions have slightly acidic surface layers underlain by neutral layers due to H_2S and iron pyrites production under anaerobic conditios.

Punjab and Haryana

Haryana

Panipat district is having the highest rice productivy (6t/ha). Except the district of Jhajhar and Bhiwani where rice productivity is low ranging from 1-1.5t/ha, all the districts are high to very high in rice productivity. The reason for low productivity in the districts are very low N and P status**.**

Punjab

Rice productivity falls under very high category in almost all the district. Most of the soils are although low to medium in NPK status. The reason is best management practices being adopted in almost all the district.

1. Toxicity of Se in Jind and Karnal districts have been reported.
2. Wind, Water erosion is the major problem.
3. Salinity, waterlogging and excessive permeability, crusting, calcareousness and poor soil structure are the major limitations in the soil.
4. Fertilizer use efficiency is low in lowland rice as well as upland situations.
5. Multinutrient deficiency is being widely reported from the crops and cropping systems.
6. Fertilizer recommendations based on soil test data needs regular updating.
7. Nutrient interactions studies and its potential use in fertilizer recommendation can bring benefit to resource poor farmers.
8. Declining response per unit area.
9. Increasing deficiency of K, Zn, Mn, S and Fe
10. Rapidly declining water table in many districts in Punjab and 11 out of 16 districts in Haryana.
11. Rising water table, salinity and sodicity in five districts of Haryana.
12. Increasing problem of disposal of rice straw and turnout

time for sowing of rabi crops after rice.
13. Burning of straw causing pollution problems.
14. Increasing problems of deterioration of quality of ground water.
15. In these soils surface crusting after the rainfall is acommon feature and impedes seed germination.
16. Presence of hard layer below the normal plough depth in these soils hinders movement of water and penetration of plant roots into the sub-soil.
17. Presence of calcium carbonate at shallow depths reduces water holdig capacity of the soils and interferes with normal root growth.

Uttar Pradesh

Most of the districts of UP are high in rice productivity where it ranges from 2 to 2.5 t/ha. However some districts like Gonda, Balrampur, Shrawasthi, Banda, Maharaj, Etah, Mainpuri, MM Nagar, Agra, Sitapur, Kannauj, Farrukabad, kanpur are low to nedium in rice productivity where it ranged from 1.5 to 2 t/ha. The reason being low to medium NPK status.

Uttaranchal

Except the district of US Nagar and Pilibhit where rice productivity is very high > 2.5t/ha, rest all the districts are medium in rice productivity. The reason being Low to medium NPK status.

Soils of Jammu and Kashmir and their fertility status.
1. Soils of the area are generally coarse in texture.
2. Soils are low in organic matter
3. Soils vary greatly in their water holding capacity.
4. Soils are highly erodible
5. Being low in particle binding materials, these soils get easily dispersed under the impacts of rain drops, resulting in crust formation on the soil surface.

Himachal Pradesh

Rice productivity is low in a most of the district ranging from 1-1.5 t/ha. The low to medium soil available P status can be one important reason.

Other soil fertility related constraints
1. Floodplain soils are most common in Una, Indora and Poanta areas, where the floodplain is dominant physiography. These soils are low in organic matter status and are of calcareous in nature.
2. Slightly to strongly acidic soils are found in grey brown podzolic soils of Kangra and Mandi district.
3. Soils are imperfectly drained and Fe-Mn concretions are found in Planosolic soils of Bilaspur and Kullu districts.
4. Acid soil infertility syndrome is quite common in Himachal Pradesh
5. Acid soils are having high and toxic concentration of Al,Fe and Mn and low availability of Ca, Mg, P and Mo.
6. Entire state faces the problem of severe erosion.
7. Shallow soil depth is very common.
8. Severe limitation in cultivation occurs due to strongly sloping lands and also falling under class IV.
9. No fertilizer schedule is available under whole cropping season.
10. Shallow soil depth
11. Sandy to loamy skeletal soils with low water holding capacity.

Orissa

Rice productivity in general is very low ranging from 1.5t/ha to less than 1 t/ha. The reason being low available N status.

Jammu & Kashmir

Except Anantnag and Baramulla district where rice productivity is high ie ranging from 2-2.5t/ha rest all the districts are low to medium in rice productivity.
1. Soils of temperate and sub tropical regions are deficient in available P than those of intermediate zone.
2. Eroded areas of Kashmir valley such as Karewas are usually deficient in available N
3. Acid soils are highly deficient in P and K.
4. Shallow soil depth
5. Sandy to loamy skeletal soils with low water holding capacity.
6. Variation in soil depth and texture in a top sequence results in differential soil water storage in the soil profile.

Karnataka

Except the district of Bidar and Dharwad where rice productivity is very low <1t/ha, rest all the districts are high in rice productivity. The impending reason can be acidity related infertility syndrome.

Other soil fertility constraints
1. Soils of Malnad coastal and hilly areas are generally deficient in Ca and Mg.
2. S is widely deficient in soils of coastal districts.
3. Zn deficiency is widespread all over the state.
4. Fe deficiency in a calcareous soils.
5. Boron deficiency has been reported from Mandya and Mysore.

Maharashtra

Except the district of Kolhapur where rice productivity is very high (2.53t/ha), rest all the district is very low in rice production and productity. The reason being low acreage of rice and low available N and P status.

Other soil fertility constraints
1. Vast tracts of lands have been rendered uncultivable due to accumulation of salts along the west coast.
2. Alkali soils occur I patches in low lying areas at the farm level.
3. low organic matter status
4. Hard setting and surface sealing soils.

West Bengal

Rice productivity falls under high category where it ranged from 2 to 2.5t/ha. Although available NPK status is low to medium. The reason being best management practices and no limitation of other soil physical constraints.

Orissa
1. Acid forming fertilizers such as urea creates unfavorable soil environment.
2. In coarse textured soils surface run off of nutrients is common.
3. Losses of N in the form of ammonium or nitrate ions are very high reducing the fertilizer use efficiency.
4. Water soluble P sources often result on poor fertilizer use efficiency due to its quick reversion to citrate soluble and insoluble forms.
5. For varying period soil moisture stress is very common

6. Soil compaction by hard setting due to plinthide foraton in the red and lateritic soils of the region is a slo a major constaint.
7. Undulating topography and palteued land creates unfavourable envorimnet.
8. Soil crusting is also a problem
9. Soil erosion is a mjor constraint.

Jharkhand

Almost all the districts of Jharkhand are low tp very low in rice productivty where it ranges from below 1t/ha to 1.5 t/ha. The extent and distribution of acidity related soil fertility syndrome can be one of the important reason.

Other soil fertility constraints

Acid forming fertilizers such as urea creates unfavourable soil environment.

1. In coarse textured soils surface run off of nutrients is common.
2. Losses of N in the form of ammonium or nitrate ions are very high reducing the fertilizer use efficiency.
3. Wter soluble P sources often result on poor fertilizer use efficiency due to its quick reversion to citrate soluble and insoluble forms.
4. For varying period soil moisture stress is very common
5. Soil compaction by hardsetting due to plinthide formation in the red and lateritic soils of the region is a slow a major constraint.
6. Undulating topography and platteued land creates unfavorable environment.
7. Soil crusting is also a problem
8. Soil erosion is a mjor constraint.
9. Negative balance between addition and removal of bases like Ca& Mg
10. Low buffering capacity of soils.
11. poor water retention and transmission characteristics
12. poor soil structure including crusting, sealing, compaction and hardening, obstruction to tillage operations.

Chhattisgarh

Jashpur district of Chhattisgarh is having the lowest rice productivity according to the table where rice productivity is less than 1 t/ha. The available N and P status is highly limiting. Rest all the districts have low productivity of rice where it ranges from 1-1.5t/ha. Most of the soils of the districts are having low N and P status.

Madhya Pradesh

Most of the districts of Madhya Pradesh are low in rice productivity due to low extent and distribution of rice area and productivty and the low N and P status.

Tamil Nadu

Rice productivity falls under high category where it ranged from 2 to 2.5t/ha. The reason being medium to high N status.

Kerala

Except Ernakulam, Kozhikode and Kannur district where rice productivity is medium ranging from 1.5to 2 t/ha, rest all the districts are high in rice productivity. The reason being low to medium in NPK status.

North Eastern Hill Regions

Meghalaya

All the districts are low to medium in rice productivity. The widespread deficiency of NPK is the reason for low productivity.

Arunachal Pradesh

Almost all the districts are low to medium in rice productivity. The reason being Low available K status.

Tripura

North and south districts of Tripura are having high to very high in rice productivity. Two of the other district such as East and West districts are medium in rice productivity.

Manipur

Except Tamenglong district of Manipur where rice productivity is very low ie < 1 t/ha, rest all the districts are having medium to highto very rice productivity.

Nagaland

All the districts are medium in rice productivity. The reason being low to medium NPK status.

Sikkim

All the districts are medium in rice productivity, the reaossn being LOW N and K status.

Mizoram

Most of the districts are medium to high in rice productivity.

1. The entire soils of the NE are almost deficient to low in available phosphorus, low to medium in potassium availability.
2. Most of the soils are high in organic matter as a result of humid climate favouring good vegetation and acidic soil reaction.
3. Almost all the soils are acidic. As such acidic soil reaction is not the limiting factor for rainfed-waterlogged rice as a result of the increase of pH after submergence to around neutral pH. Rice is considered one of the tolerant crop to soil toxic aluminium, so it can only become limiting to upland rice production in Jhum and sloppy land when soil pH drops below 4.5.
4. The status of micronutrients in respect of total and available Cu and Zn do not vary much among the both type of soils and some soils are rated low in available Zn.

a. Since, fertilizer use is low in NE (excepting Manipur) resulting serious nutrient depletion in almost every state of northeastern India.

5. Among the fertilizers used, nitrogen dominates at present, and thereby affecting the balance use of plant nutrients for crops. The response of rice to fertilizers has been well documented in the region and is briefed below.
6. The productivity of rice is limited by the availability of N excepting very few soils high in organic matter at lower elevations.
7. Although higher altitude soils are high in total P reserve due to high amount of organic matter, low soil temperature results lower mineralisation of organic P, which in turn, minimizes the available P supplying power of soils. The critical limit of available P (Bray 2) determined for wetland rice was found to be 12 ppm P.
8. The deficiency of K occurs frequently on sandy, degraded ill-drained and highly reduced valley soils.
9. Loss of top fertile soils from terraces and sloppy lands by runoff water also causes its deficiency in uplands.
10. Among the micronutrients, the deficiency of zinc and boron are possible in the soils caused by adsorption on the oxides of iron and aluminium besides leaching of

later due to heavy rainfall in light textured soils.

Conclusion

The yield level of a crop reflects many facets of crop growth including environmental factors such as rainfall, temperature, sunlight and humidity and cultural factors such as planting date, row spacing, cultivar selection and tillage method. As a result, the interpretation of a relationship is difficult; however response is likely at low yields at high soil test values. While the diversity in agro ecological environment in the country provide opportunities for growing numerous commercially viable cropping and farming systems towards a robust agriculture, efficient and sustainable management of natural resources especially soil and water for enhanced soil productivity is vital for over all economy of the country. Although soil productivity depends largely on a number of its diverse physico - chemical and biological characteristics, the ultimate output is governed by the precise agronomic operations, matching production systems with land capability, efficient management of external inputs like seed, water, nutrient etc., and maintaining a synergy between conservation and exploitation of resources such as soil and water.

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